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Process to prepare alkyl phenyl phosphates

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ACD 3021 PDEP

## PROCESS TO PREPARE ALKYL PHENYL PHOSPHATES

The present invention relates to a process to prepare alkyl phenyl phosphates.

6 A process to prepare alkyl phenyl phosphates is described in US 2,504,121. Monalkyl diaryl phosphate esters are prepared by reaction of an alkylchlorophosphate and a phenolate compound. The alkylchlorophosphate is formed in a preceding step by reaction of phosphorus oxychloride and an alcohol. The phenolate compound is formed by reaction of phenol compound  
10 and a base.

A process to prepare alkyl phenyl phosphates is also known from US 6,299,887. In this publication an alkyl phenyl phosphate, more specifically (2-heptylundecyl)diphenyl phosphate, is synthesised by reaction of diphenyl  
15 phosphoryl chloride with 2-heptylundecyl alcohol in the presence of a triethylamine catalyst and an acid amine scavenger.

The present invention aims to provide an alternative and simplified process for the preparation of monoalkyl diaryl phosphate esters and dialkyl monoaryl phosphate esters wherein no amine scavenger needs to be used, while at the  
20 same time it results in a very pure product and a low level of triphenyl phosphate. Further, the process according to the invention is improved in that it can be carried out in the absence of solvent, strong bases, and an acid amine scavenger, which is advantageous. Further, the invention aims to provide an  
25 economical process that gives a low amount of chlorinated by-products and a low acid value. Moreover, the invention aims to provide a process wherein only a slight molar excess (compared to stoichiometric) of alcohol is required to react with the chloro in the monophenyl dichlorophosphate and/or diphenyl monochlorophosphate compounds, while at the same time a good overall yield  
30 of alkyl phenyl phosphate is acquired.

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In the process according to the invention, dichloromonophenyl phosphate and/or monochlorodiphenyl phosphate is reacted with an aliphatic alcohol in the presence of a Lewis acid catalyst and in the absence of solvent at a temperature of 40 to 200°C and a pressure of 0 to 1 bar.

5

Further, the process is performed at low H<sub>2</sub>O levels, such that any HCl generated is efficiently removed, with high yields at low catalyst concentrations.

10 In a preferred embodiment, the HCl is removed by sparging with a carrier, preferably by sparging with an inert gas such as nitrogen gas.

In a more preferred embodiment, the present invention relates to a process to prepare alkyl phenyl phosphates at a pressure below atmospheric pressure, preferably a pressure of at least 0.001 bar and at most 0.99 bar.

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In a first embodiment, the pressure is at least 0.25 bar and at most 0.98 bar, preferably at least 0.3 bar and at most 0.95 bar, most preferably at least 0.35 and at most 0.9 bar, because it is economically more attractive. However, at this pressure it is necessary to use a carrier gas to efficiently remove the HCl that is

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formed.

In another embodiment, a pressure of 0.001 to 0.065 is preferred, even more preferably 0.002 to 0.06, most preferably 0.003 to 0.05 bar. A process at such low pressure does not require the use of a sparging gas to achieve the desired

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product quality.

In another preferred embodiment, the present invention relates to a process to prepare a mixture of monoalkyl diphenyl phosphate and dialkyl monophenyl phosphate.

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The invention further relates to alkyl phenyl phosphates and alkyl phenyl phosphate mixtures obtainable by such process and the use thereof as plasticisers.

- 5 EP-A-0 775 147 describes a process to prepare a mixture of a monoalkyl diphenyl phosphate and a dialkyl monophenyl phosphate. More specifically, the synthesis of a mixture of isododecyl diphenyl phosphate and diisododecyl monophenyl phosphate by transesterification of triphenyl phosphate with isododecyl alcohol and the synthesis of a mixture of 2-ethylhexyl diphenyl  
10 phosphate and di-2-ethylhexyl monophenyl phosphate by transesterification of triphenyl phosphate with 2-ethylhexyl alcohol are described.

However, this process results in a mixture having a high residual amount of triphenyl phosphate, which for various reasons (e.g. from a product  
15 performance or ecological point of view) is disadvantageous in some applications. Further, this process is hard to control and not economical. Moreover, in this process (contaminated) phenol is formed as a by-product, which is disadvantageous.

- 20 The current process aims at providing an alternative process to prepare a mixture of monoalkyl diphenyl phosphate and dialkyl monophenyl phosphate which is improved in that only very low levels of triphenyl phosphate are present in the resulting product.
- 25 The process of this embodiment is characterised in that a mixture of diphenyl monochlorophosphate and monophenyl dichlorophosphate is reacted with an aliphatic alcohol in the presence of a Lewis acid catalyst and in the absence of solvent at a temperature of 40 to 200°C and a pressure of 0 to 1 bar.
- 30 Further, the process is performed at low H<sub>2</sub>O levels, such that any HCl generated is efficiently removed, with high yields at low catalyst concentrations.

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In US 6,299,887 the process to prepare a mixture of a monoalkyl phenyl phosphate and a dialkyl monophenyl phosphate by reacting a mixture of monophenyl dichlorophosphate and diphenyl monochlorophosphate with an aliphatic alcohol is not taught or suggested

5

Further, it should be noted that in US 6,242,631 a mixture of monophenyl dichlorophosphate and diphenyl monochlorophosphate is used as a starting mixture to prepare a mixture of substituted phenyl-phenyl phosphates. For example, a mixture of monophenyl dichlorophosphate and diphenyl monochlorophosphate reacts with phenyl alcohol in the presence of magnesium chloride and in the absence of solvent at a temperature of 145°C and atmospheric pressure.

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In US 5,457,221 a mixture of monophenyl dichlorophosphate and diphenyl monochlorophosphate is used as a starting mixture to prepare polyhydrocarbylene aryl phosphate compositions. For example, a mixture of monophenyl dichlorophosphate and diphenyl monochlorophosphate reacts with an aromatic diol in the presence of magnesium chloride and in the absence of solvent at a temperature of 150°C and atmospheric pressure.

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However, in these two publications is the reaction of such a mixture with a non-phenolic alcohol neither disclosed nor suggested, nor is the production of a mixture of monoalkyl diphenyl phosphate and dialkyl monophenyl phosphate. US 2,504,121 even teaches that the reaction of a phenyl chlorophosphate compound with an aliphatic alcohol is objectionable, as the reaction is difficult to control and excessive quantities of triaryl phosphates are formed.

25

Surprisingly, it has now been found that the reaction of a mixture of diphenyl monochlorophosphate and monophenyl dichlorophosphate with an aliphatic alcohol can be performed without the formation of an excessive amount of triaryl phosphates or other undesirable by-products and is controllable provided that the right reaction conditions are chosen. The alkyl phenyl phosphate

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products formed further have good characteristics as plasticisers, for example in PVC applications.

5 The process is further characterised in that it results in a mixture containing a larger amount of diphenyl monoalkyl phosphate and a smaller amount of monophenyl dialkyl phosphate. More specifically, the resulting mixture should contain 25 to 99.9 weight%, preferably 35 to 99 weight%, more preferably 40 to 98 weight%, even more preferably 45 to 95 weight% diphenyl monoalkyl phosphate, based on the total amount of phenyl alkyl phosphates.

10 In the resulting mixture of alkyl phenyl phosphates preferably less than 10 wt% of triphenyl phosphate is present, based on the total amount of phenyl phosphate compounds, more preferably less than 5 wt%, even more preferably less than 4 wt%, most preferably less than 3 wt%.

15 In a preferred embodiment of this process to prepare a mixture of alkyl phenyl phosphates, the HCl by-product is removed by sparging with a carrier, preferably by sparging with an inert gas such as nitrogen gas.

20 In this description "in the absence of solvent" or "solvent-free" means that less than 5 wt% solvent is used, preferably less than 3 wt%, more preferably less than 2 wt%, even more preferably less than 1 wt%.

25 It is further noted that in this description the term bar is used for the absolute pressure in bar (bara).

30 By the term phenyl phosphate is meant a phosphate esterified with a phenyl group and/or a substituted phenyl group such as a phenyl group substituted with a C1-C6 alkyl group, a C1-C6 alkoxy group. Preferably, the phenyl group is an unsubstituted phenyl group.

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The present invention further relates to a two-step process wherein in a first step (preceding the reaction of the mixture of the monophenyl dichlorophosphate and diphenyl monochlorophosphate with an alcohol) the mixture of monophenyl dichlorophosphate and diphenyl monochlorophosphate  
5 is prepared. In this first step phosphorus oxychloride is reacted with phenol.

Preferably, during this first step a Lewis acid catalyst is present, the pressure is an atmospheric pressure or enhanced pressure, and the temperature is between 100 and 200°C. More preferably, the pressure is between 1 and 1.5  
10 bar and the temperature between 105 and 160°C.

In an especially preferred embodiment of the two-step process, (all) Lewis acid catalyst is added in the first step of the process and in the second step of the process no additional Lewis acid catalyst is added.

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The ratio of phosphorus oxychloride to phenol is 1 to 2, preferably 1 to 1.5, even more preferably 1.05 to 1.4, most preferably 1.1 to 1.3.

In a preferred embodiment of the two-step process, monophenyl dichlorophosphate resulting from the first step is (partly) recycled in the process and again reacted (in the first step) with phenol, such that the ratio of diphenyl monochlorophosphate to monophenyl dichlorophosphate in the mixture that subsequently reacts with aliphatic alcohol increases. In this way the ratio of diphenyl monoalkyl phosphate to monophenyl dialkyl phosphate and the  
20 content of triphenyl phosphate in the resulting mixture can be tailored to the  
25 actual requirements.

30

In another preferred embodiment, the two-step process, optionally including the recycling of monophenyl dichlorophosphate, is performed continuously.

In a further preferred embodiment, in this two-step process to prepare alkyl phenyl phosphates the HCl by-product (in either the first and/or the second



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reaction step) is removed by sparging with a carrier, preferably by sparging with an inert gas such as nitrogen gas.

The Lewis acid that can be used in the processes according to the invention  
5 includes any Lewis acid capable of promoting the reaction as known to the person skilled in the art and includes the halides of Group II and Group III metals. As examples may serve  $\text{AlCl}_3$ ,  $\text{TiCl}_4$ ,  $\text{ZnCl}_2$ ,  $\text{CaCl}_2$ ,  $\text{MgCl}_2$  (or their respective bromides or iodides), and  $\text{MgO}$ . Preferred Lewis acids are aluminium chloride ( $\text{AlCl}_3$ ) and magnesium chloride ( $\text{MgCl}_2$ ). Most preferred is the Lewis  
10 acid magnesium chloride.

The aliphatic alcohol can be any alcohol known to the person skilled in the art wherein a hydroxyl group is linked to a  $\text{C}_1$ - $\text{C}_{16}$  hydrocarbon group. The hydrocarbon group can be branched or linear, cyclic or non-cyclic, can be a  
15 completely saturated or partly unsaturated hydrocarbon group, and can comprise substituents such as aryl groups and substituents that contain heteroatoms such as halogens, oxygen, sulphur, and nitrogen, which substituents may themselves be substituted with further substituents. Preferred aliphatic alcohols for use in the processes of the invention include saturated  $\text{C}_1$ -  
20  $\text{C}_{16}$  alcohols. Examples of the most preferred aliphatic alcohols are n-butanol, i-butanol, 2-ethylhexanol, n-octanol, i-octanol, n-decanol, i-decanol, n-dodecanol, i-dodecanol, and cyclohexanol.

The molar ratio between the hydroxyl groups in the aliphatic alcohol and the  
25 chloro groups in the monochlorodiphenyl phosphate and/or dichloromonophenyl phosphate preferably is 1:1 to 1.5:1, more preferably 1:1 to 1.3:1, even more preferably 1:1 to 1.2:1, and most preferably 1:1 to 1.1:1.

The processes according to the invention may optionally comprise an additional  
30 purification step. Such purification step may include washing the product, vacuum distillation or wiped film evaporation. Preferably, the product is purified by washing. More preferably, washing is done in a number of steps using water

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and/or aqueous solutions with up to 10 wt% of a base or acid, even more preferably 0.2 to 5 wt%, most preferably 0.5 to 2 wt% of a base or acid. The base or acid can be any base or acid known by the person skilled in the art to be soluble in water and suitable for washing a product. Suitable acids include

5 HCl, H<sub>2</sub>SO<sub>4</sub>, H<sub>3</sub>PO<sub>4</sub>, CH<sub>3</sub>COOH, HOOC-COOH. Particular preference is given to HOOC-COOH, in particular in a concentration range from 0.5 to 10% in water. Suitable bases for the alkaline wash include conventional basic salts such as NaOH, Na<sub>2</sub>CO<sub>3</sub>, NaHCO<sub>3</sub>, sodium acetate, and corresponding potassium salts. Among these the sodium salts are more preferred, in particular NaOH in a

10 concentration range from 0.5 to 10% in water.

The processes according to the invention may be a continuous, semi-continuous or batch process.

15 In the processes according to the invention the amount of Lewis acid generally is above 10 ppm, based on the total amount of phenyl chlorophosphate starting materials, preferably the amount of Lewis acid catalyst is above 100 ppm, more preferably above 150 ppm, even more preferably above 200 ppm, most preferably above 800 ppm. The amount of Lewis acid generally is below 3,000

20 ppm; based on the total amount of phenyl chlorophosphate starting materials, preferably the amount of Lewis acid catalyst is below 2,000 ppm, more preferably below 1,750 ppm, even more preferably below 1,500 ppm, most preferably below 1,000 ppm.

25 In the embodiment relating to a two-step process wherein the Lewis acid is added completely at the first step, the amount of Lewis acid is in the same ranges as given above, based on phenyl chlorophosphate products resulting from the first step.

30 In the processes of the invention, sparging with a carrier is preferably done with a sparge flow of 1 to 100 m<sup>3</sup>/h, preferably of 2 to 75 m<sup>3</sup>/h, more preferably of 4 to 50 m<sup>3</sup>/h.

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The invention also relates to the alkyl phenyl phosphates and alkyl phenyl phosphate mixtures obtainable by the processes according to the current invention. These alkyl phenyl phosphates and alkyl phenyl phosphate mixtures have good characteristics as plasticisers and are further suitable for use as flame retardants and lubricants.

The alkyl phenyl phosphate mixtures in general have a desired ratio of diphenyl monoalkyl phosphate to monophenyl dialkyl phosphate of 1:1 to 100:1, preferably 2:1 to 90:1, more preferably 5:1 to 80:1, even more preferably 10:1 to 70:1, most preferably 15:1 to 50:1.

Additionally, the invention relates to the phenyl alkyl phosphates and phenyl alkyl phosphate mixtures as plasticisers, lubricants and/or flame retardants. The phenyl alkyl phosphate mixtures according to the invention are of particular use as plasticisers, preferably as plasticisers in PVC applications

The present invention is further illustrated by the following Examples

#### Examples

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Laboratory scale experiments were done in a 2-litre jacketed glass reactor equipped with a 4-blade propeller agitator, a condenser, and a sub-surface liquid addition capability. A Vacuubrand diaphragm vacuum pump was used to control the vacuum in the reactor. A caustic scrubber was used to scrub hydrogen chloride formed in the reaction.

25

Scale-up experiments were done in 400- and 7,500-litre glass-lined jacketed reactors equipped with an agitator, a condenser, and a sub-surface liquid addition capability. Effluent gas from the reactor was scrubbed with water. Vacuum in the reactors was controlled by using either a liquid-ring vacuum pump or steam jet ejectors.

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Purification of the crude reaction mixture was done using sequential washing in the same reactor vessel. Aqueous solutions were added to the product at 60°C and agitated for about 30 minutes. The mixture was then allowed to phase separate for about 30 min. After the final washing step, the product was  
5 dehydrated under vacuum to remove water carried over from the washing process. The dehydrated product was filtered using standard filtration equipment. In commercial application steam and/or N<sub>2</sub> sparging could be used to further purify the dehydrated product and/or fractional distillation stripping could be used to further reduce the residual alcohol and chloride contents.

10

The reaction feeds, crude reaction product, and finished product were analysed for their composition by gas chromatography using a FID detector. In addition, wet analysis and potentiometric titration were used to measure acid phosphate composition, dissolved HCl, and acid numbers in the crude reaction product and  
15 finished product samples.

### Examples 1 to 6

20 To the phosphochloridate mixture (6.4 wt% phenyl dichloridophosphate (MPCP), 89.7 wt% diphenyl chloridophosphate (DPCP), 3.9% triphenyl phosphate (TPP), and about 0.1wt% MgCl<sub>2</sub>) 2-ethylhexanol was added via sub-surface addition at reaction conditions. Table 1 summarises the reaction conditions and the crude product compositions for both the laboratory scale and  
25 pilot scale experiments. Acceptable product quality is achieved under all reaction conditions summarised in Table 1. Efficient HCl removal is required for minimising the by-product formation. In these examples vacuum is the key method for HCl removal.

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**Examples 7 and 8**

The crude from the reaction mixture of Example 1 and Example 5 was washed using the following sequence:

- 1% oxalic acid solution wash.
- 1% NaOH solution wash.
- Water wash.
- Water wash.

5

The composition of the product after purification by washing is summarised in Table 2.

Example	Reaction Scale [ Litres]	Reaction Feed Amounts [kg]	Reaction Conditions					Crude Reaction Product Composition						
			DPCP mix <sup>1</sup>	2-EH <sup>2</sup>	T °C]	P [mmHg]	Addition Time [Hrs]	Post Addition Reaction [Hrs]	2-EHC1 <sup>3</sup> [wt%]	2-EH <sup>2</sup> [wt%]	TPP [wt%]	2-EHDPPPh <sup>4</sup> [wt%]	2-EHPPPh <sup>5</sup> [wt%]	DPAP <sup>6</sup> [wt%]
1	2	1	0.528	120	150	1.5	4	1.6	ND	3.2	81.4	9.6	4.2	7.6
2	2	1	0.528	120	150	1.5	4	1.5	0.5	3.3	81.3	9.7	3.7	7.3
3	2	0.500	0.264	120	150	3	4	1.2	0.8	3.3	81.4	9.7	3.7	7.9
4	2	0.500	0.264	120	50	1.5	4	0.7	0.4	3.3	84.1	10.0	1.5	2.9
5	400	120.2	63.5	120	150	2	4	3.0	ND	3.4	81.0	9.8	2.2	6.6
6	400	228.6	118.1	120	50	3	4	1.3	ND	3.2	86.4	7.1	2.3	5.3

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Table 1. Summary of experimental conditions and crude reaction product compositions for Examples 1 through 6.

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<sup>1</sup>DPCP mix – phosphochloridate mixture with the following composition - 8.4 wt% phenyl dichloridophosphate (MPCP), 89.7 wt% diphenyl chloridophosphate (DPCP), 3.9% triphenyl phosphate (TPP), and about 0.1 wt% MgCl<sub>2</sub>.  
<sup>2</sup> 2-EH – 2-ethylhexanol, <sup>3</sup>2-EHCl – 2-ethylhexylchloride, <sup>4</sup>2-EHDPPH – 2-ethylhexyldiphenyl phosphate, <sup>5</sup> bis(2-ethylhexyl) phenyl phosphate, <sup>6</sup> DPAP- diphenyl acid phosphate.

5

Table 2.

Example	Crude	Washing Conditions			Product Composition after purification						Acid Number [mg KOH/g]
		T [°C]	Agitation Time [min]	Settling Time [min]	2- EHCl <sup>1</sup> [wt%]	2- EH <sup>2</sup> [wt%]	TPP	2- EHDPPH <sup>3</sup> [wt%]	2- EHPPH <sup>4</sup> [wt%]	DPAP <sup>5</sup> [wt%]	
7	From Example 1	60	30	30	1.2	ND	3.4	85.4	10.0	ND	
8	From Example 2	60	30	30	1.1	0.5	3.4	85.0	10.1	ND	
9	From Example 5	60	30	30	1.3	1.0	3.3	83.7	10.7	ND	

Composition of product samples after purification (Examples 7 and 8).

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**Examples 9 through 12**

To the phosphochloridate mixture (6.3 wt% phenyl dichloridophosphate (MPCP), 91.2 wt% diphenyl chloridophosphate (DPCP), 2.3% triphenyl phosphate (TPP), and 0.1wt%  $\text{MgCl}_2$ ) isodecyl alcohol (EXXAL-10) was added via sub-surface addition at reaction conditions. The isodecyl alcohol used in these examples is comprised of mixed isomers. Table 3 summarises the reaction conditions and the crude product compositions for both the laboratory scale and pilot scale experiments. Acceptable product quality is achieved under all reaction conditions summarised in Table 3. Efficient HCl removal is required for minimising the by-product formation. In these examples vacuum is the key method for HCl removal.

**Examples 13 and 14**

In these examples the reaction between the phosphochloridate mixture and isodecyl alcohol was conducted in a batch fashion instead of the semi-batch operation. To the phosphochloridate mixture (401 gms) with the composition summarised in Examples 9 through 11 isodecylalcohol (253 gms) was added at room temperature. The mixture was brought to 100°C and 100 mm Hg. The reaction was carried out for 4 hours and the crude was analysed. The crude composition is summarised in Table 4.

**Examples 15 and 16**

The crude product obtained from Example 10 and Example 12 was further purified by washing using the following sequence:

- 1% oxalic acid solution wash.
- 1% NaOH solution wash.
- Water wash.
- Water wash.

The composition of the purified product is summarised in Table 4.

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**Example 17**

The purified product of Example 16 was further purified by steam stripping to remove excess alcohol and alkyl chloride. Steam was sparged into the reactor containing the product via a dip tube. Vacuum was maintained between 100 mm Hg and 10 mm Hg and the temperature was varied between 80°C and 120°C. Although this experiment was conducted under non-optimised conditions, we were able to achieve significant reduction in the alcohol and chlorides from about 5.0 area% to about 0.6 area% under the experimental conditions explored. Although steam was used as the stripping agent in this example, any suitable stripping agent could be used to achieve the end result of reducing the alcohol and chloride contents.

Example	Reaction Scale [Litres]	Reaction Amounts [kg]	Reaction Conditions					Crude Reaction Product Composition						
			DPCP mix <sup>1</sup>	Isodecyl Alcohol <sup>2</sup>	T [°C]	P [mmHg]	Addition Time [Hrs]	Post Addition Reaction [Hrs]	Phenol [wt%]	Isodecyl Alcohol+Isodecyl Chloride <sup>3</sup> [wt%]	TPP [wt%]	IDDPPh + IDPPPh <sup>3</sup> [wt%]	DPAP <sup>4</sup> [wt%]	Acid Number [mg KOH/g]
9	2	0.5 <sup>1</sup>		0.317	120	50	2	2	ND	5.6	1.5	87.1	6.3	14.0
10	2	0.401 <sup>1</sup>		0.284	100	50	3	4	0.19	3.95	1.5	90.45	3.7	8.4
11	2	0.432 <sup>1</sup>		0.284	90	50	2	5	0.17	2.7	1.5	94.6	2.8	6.2
12	7500	4493 <sup>2</sup>		2698	90	50	5	2	0.28	5.4	3.7	86.2	2.5	7.2

10

Table 3. Summary of experimental conditions and crude reaction product compositions for Examples 9 through 12

<sup>1</sup> DPCP Mix - 6.3 wt% phenyl dichloridophosphate (MPCP), 91.2 wt% diphenyl chloridophosphate (DPCP) and 2.3% triphenyl phosphate (TPP).

<sup>2</sup> DPCP Mix - 5.7 wt% MPCP, 86.2% DPCP and 6.8% TPP.

<sup>3</sup> Isodecyl Alcohol (EXXAL-10 obtained from Exxon Mobil) comprised of mixed isomers.

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<sup>4</sup> GC method used in general did not differentiate between alkyl chlorides and isodecyl alcohol.  
<sup>5</sup> IDPPPh – isodecyl diphenyl phosphate and IDPPPh – bis(isodecyl) phenyl phosphate are reported as one value by the GC method used in the analysis.  
<sup>6</sup> DPAP- diphenyl acid phosphate.

5

Example	Reaction Scale [Litres]	Reaction Amounts [kg]	Reaction Conditions				Crude Reaction Product Composition						
			DPCP mix <sup>1</sup>	Isodecyl Alcohol <sup>2</sup>	T [°C]	P [mmHg]	Addition Time [Hrs]	Post Addition Reaction [Hrs]	Phenol [wt%]	Isodecyl Alcohol+Isodecyl Chloride <sup>3</sup> [wt%]	TPP IDPPPh <sup>4</sup> [wt%]	IDPPPh <sup>4</sup> [wt%]	DPAP <sup>5</sup> [wt%]
13	2	0.401	0.253	100	100	Batch	4	ND	1.6	1.5	90.5	1.6	3.9

Table 4. Summary of experimental conditions and crude reaction product compositions for Examples 13 and 14

10

<sup>1</sup> DPCP Mix - 6.3 wt% phenyl dichloridophosphate (MPCP), 91.2 wt% diphenyl chloridophosphate (DPCP), and 2.3% triphenyl phosphate (TPP).  
<sup>2</sup> Isodecyl Alcohol (EXXAL-10 obtained from Exxon Mobil) comprised of mixed isomers.  
<sup>3</sup> GC method used in general did not differentiate between alkyl chlorides and isodecyl alcohol.  
<sup>4</sup> IDPPPh – isodecyl diphenyl phosphate and IDPPPh – bis(isodecyl) phenyl phosphate are reported as one value by the GC method used in the analysis.  
<sup>5</sup> DPAP- diphenyl acid phosphate.

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Example	Crude	Washing Conditions		Product Composition after purification					IDDPPh <sup>3</sup> [wt%]	+ IDDPPh <sup>3</sup> [wt%]	DPAP <sup>3</sup> [wt%]	Acid Number [mg KOH/g]
		T [°C]	Agitation Time [min]	Settling Time [min]	Phenol [wt%]	Isodecyl Alcohol+ Isodecyl Chloride <sup>3</sup> [wt%]	TPP					
14	From Example 10	60	30	30	0.01	3.4	1.5		93.4		ND	0.016
15	From Example 12	60	30	30	0.01 (GC area%)	5.0 (GC area%)	3.7 (GC area%)		91.3 (GC area%)		ND	0.01

Table 5. Composition of products of Examples 10 and 12 after purification by washing.

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## CLAIMS

1. Process to prepare dialkyl monophenyl phosphate, monoalkyl diphenyl phosphate or mixtures thereof wherein dichloromonophenyl phosphate and/or monochlorodiphenyl phosphate is reacted with an aliphatic alcohol in the presence of a Lewis acid catalyst and in the absence of solvent at a temperature of 40 to 200°C and a pressure of 0 to 1 bar.
2. A process according to claim 1 wherein a mixture of monoalkyl diphenyl phosphate and dialkyl monophenyl phosphate is produced.
3. A process according to claim 1 or 2 wherein the catalyst is magnesium chloride.
4. A process according to any one of claims 1 to 3 wherein the by-product HCl is removed by sparging with a carrier.
5. A process according to any one of claims 1 to 4 wherein the Lewis acid catalyst is used in an amount of 100 to 1,750 ppm, based on the total amount of phenyl chlorophosphate starting materials.
6. Two-step process to prepare a mixture of monoalkyl diphenyl phosphates and dialkyl monophenyl phosphates wherein in a first step dichlorophosphate is reacted with phenol and in a second step in accordance with the process according to any one of claims 1 to 5 the mixture of diphenyl monochlorophosphates and monophenyl dichlorophosphates resulting from the first step is reacted with an aliphatic alcohol.

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7. The two-step process of claim 6 wherein the Lewis acid catalyst is completely added in the first step of the process and in the second step of the process no additional Lewis acid catalyst is added.
- 5 8. The two step process of claim 6 or 7 wherein at least part of the monophenyl dichlorophosphate from the first step is recycled, so that the alkyl diphenyl phosphate to dialkyl phenyl phosphate ratio of the product mixture of the second step is greater than the diphenyl chlorophosphate to monophenyl dichlorophosphate ratio resulting from the first reaction step  
10 before the recycle stream.
9. A process according to any one of claims 1-8 comprising an additional purification step.
- 15 10. A process according to any one of claims 1-9 that is a continuous, semi-continuous or batch process.
11. Mixture of monoalkyl diphenyl phosphates and dialkyl monophenyl phosphates obtainable from the process according to any one of preceding  
20 claims 2-10.
12. Mixture of mono-2-ethylhexyl diphenyl phosphate and di-2-ethylhexyl phenyl phosphates, of i-decyldiphenyl phosphate and di-i-decyl phenyl phosphates or of i-dodecyl diphenyl phosphates and di-i-dodecyl phenyl phosphate.  
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13. Use of mixture of claim 11 or 12 as a plasticizer and/or flame retardant.

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**ABSTRACT**

The present invention relates to a process to prepare dialkyl monophenyl phosphate, monoalkyl diphenyl phosphate or mixtures thereof wherein dichloro-  
5 monophenyl phosphate and/or monochlorodiphenyl phosphate is reacted with an aliphatic alcohol in the presence of a Lewis acid catalyst and in the absence of solvent at a temperature of 40 to 200°C and a pressure of 0 to 1 bar. The present invention further relates to mixtures of monoalkyl diphenyl phosphates and dialkyl monophenyl phosphates obtainable from the above process and the  
10 use of such mixtures as a plasticiser and/or a flame retardant.

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